



GSTB-V1: The First Step Towards the Development of Galileo Navigation Algorithms

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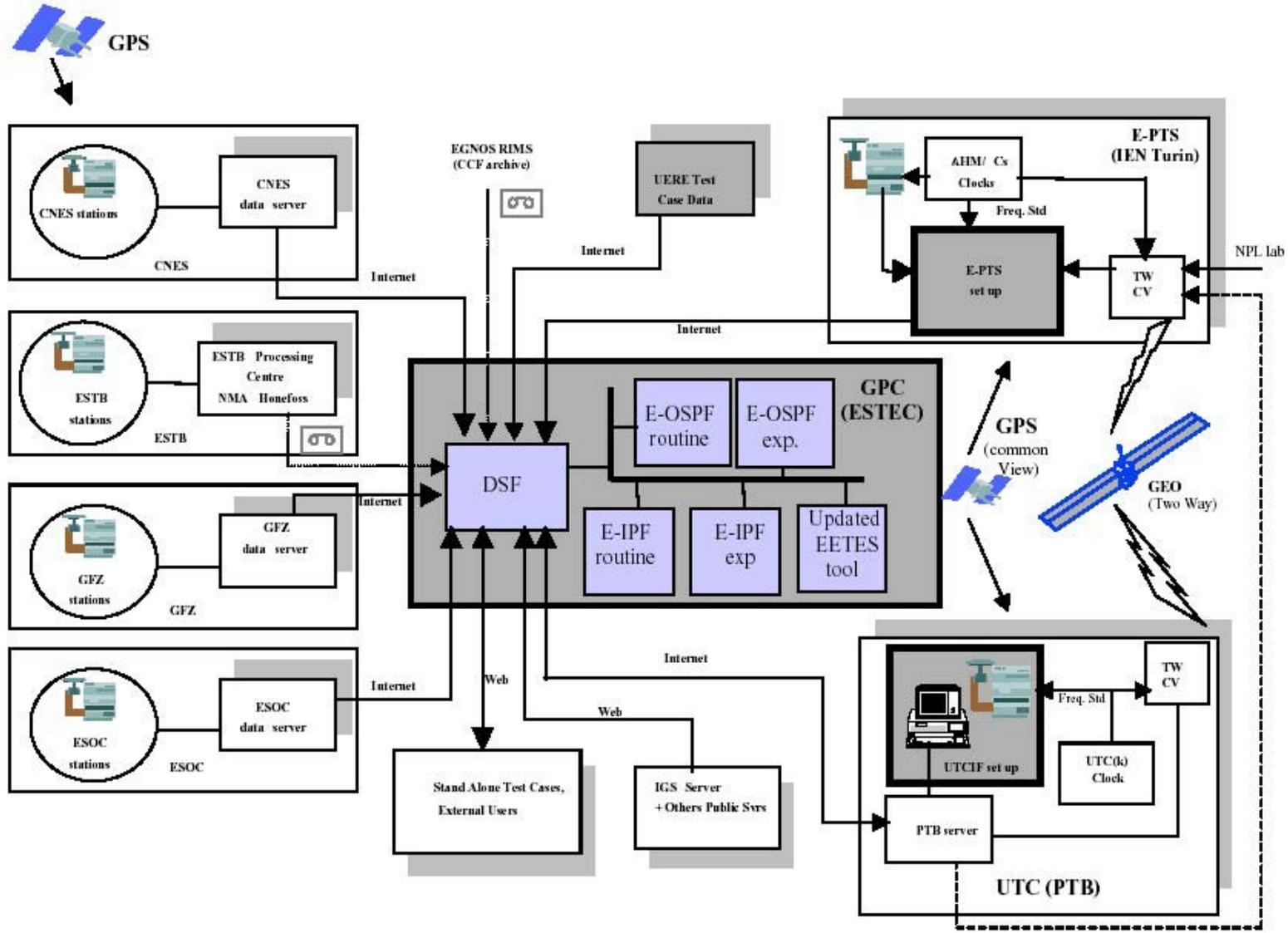


Introduction: GSTB-V1

- The GSTB-V1 is an experimentation platform developed for risk mitigation of the Galileo GMS
 - Processing of real GPS data
 - Stringent development standards
 - Documentation, testing, validation
 - Prototypes of several GMS elements
 - E-OSPF
 - E-IPF
 - E-PTS
 - Routine generation of navigation and integrity products
 - Operations plan
 - Near real-time



Introduction: GSTB-V1 (2)





Experimentation (1)

- E-OSPF holds the experimentation with prototype algorithms for
 - OD&TS, including generation of the Navigation Message
 - SISA
- Galileo OD&TS function has to consider not only the orbit and clock accuracy but also:
 - Product reliability (integrity)
 - Operational constraints
 - CPU time (may be a critical issue)
 - "Black box" (no operator intervention)
 - ROP rather than POD
- Considerations above represent key drivers for algorithm selection and architectural design



Experimentation (2)

- Navigation experimentation
 - OD&TS performance assessment (accuracy of orbit, clock and navigation message products)
 - Operational scheme similar to IGS Ultra-Rapid products (near real time)
 - Assessment of alternative algorithms
- Robustness
 - SISA
- Limited tracking network size (**20-30** GSSs)
 - **Data quality and availability**
- Use of IGS data and products
 - Data from IGS stations
 - IGS final products, used as reference for performance assessment



GMV OD&TS Algorithms (1)

- OD&TS models based on IERS Conventions 1996
 - Rock models for SRP
 - Empirical accelerations
- Baseline observable: Undifferenced iono-free pseudorange and carrier phase measurements
- Filter: Batch least squares with a-priori information
 - Ambiguities estimated as non-integer pass-dependent biases
 - Constrained estimation of station coordinates / ERPs
 - Estimation of time-dependent station zenith delays



OD&TS Algorithms (2)

○ Highlights

● Pre-processing

- Cycle slip detection and repair, using 1-Hz data
- Use of smoothed pseudorange as observable
- Resolution of ambiguity in the pre-processing

● Parameter estimation

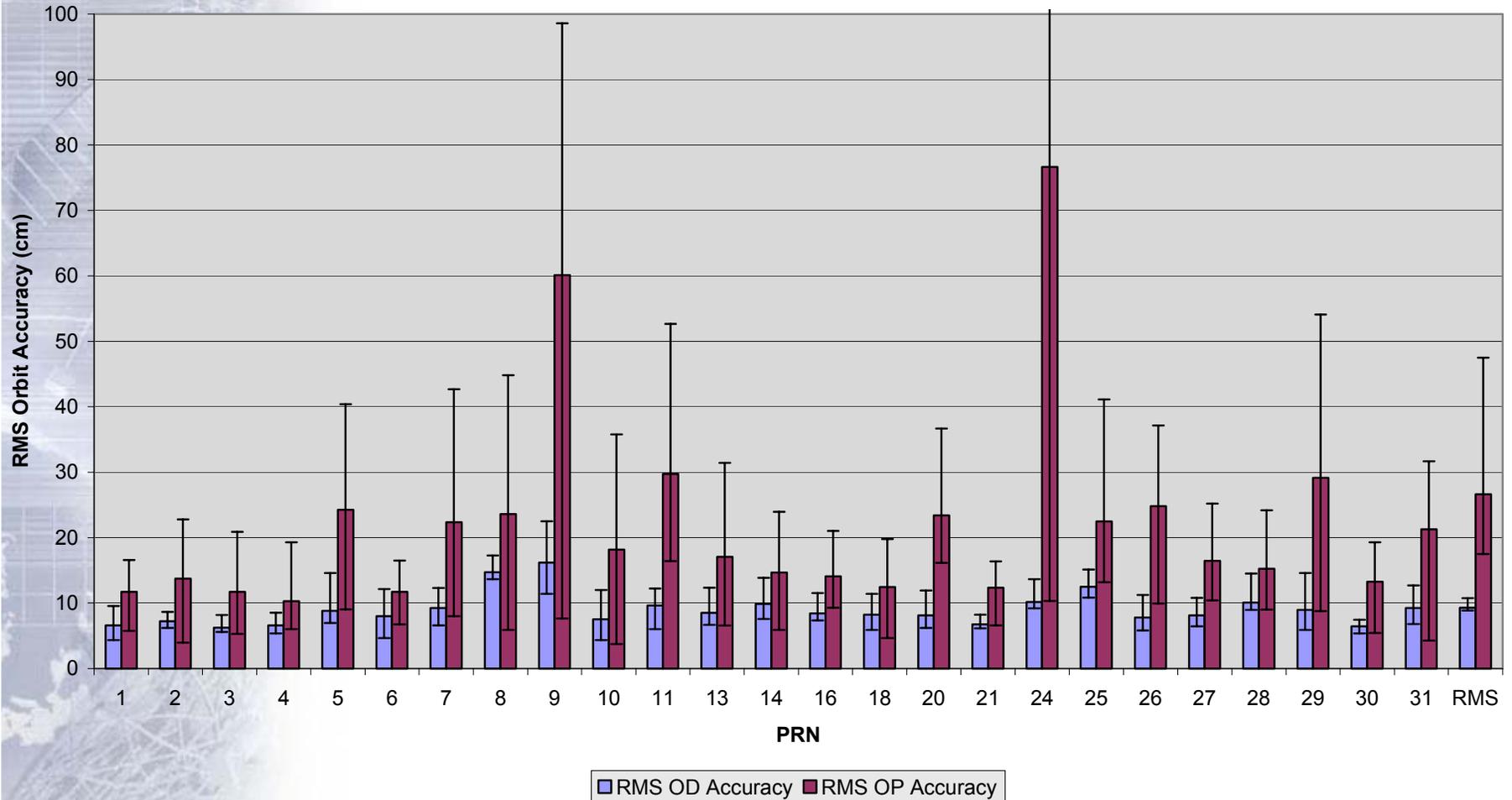
- Correlation between snapshot clocks and dynamic parameters is taken into account in the normal matrix
- Estimation of clock models (linear or quadratic) instead of snapshot values



GMV Preliminary Results (1)

RMS Orbit Accuracy (1 day = 12 sessions)

RMS of error components averaged over the full arc. Error bars show variability across sessions

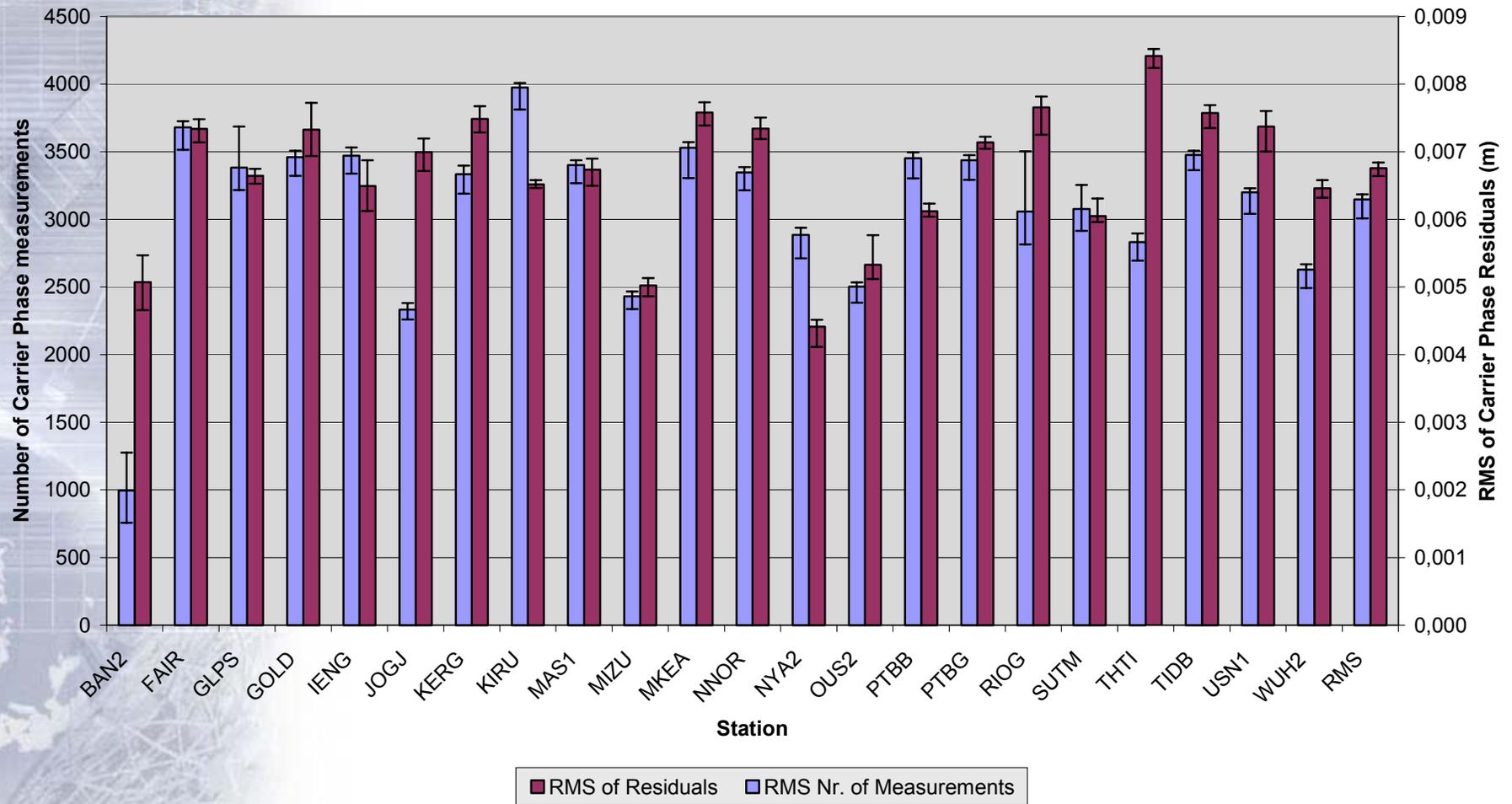




GMV Preliminary Results (2)

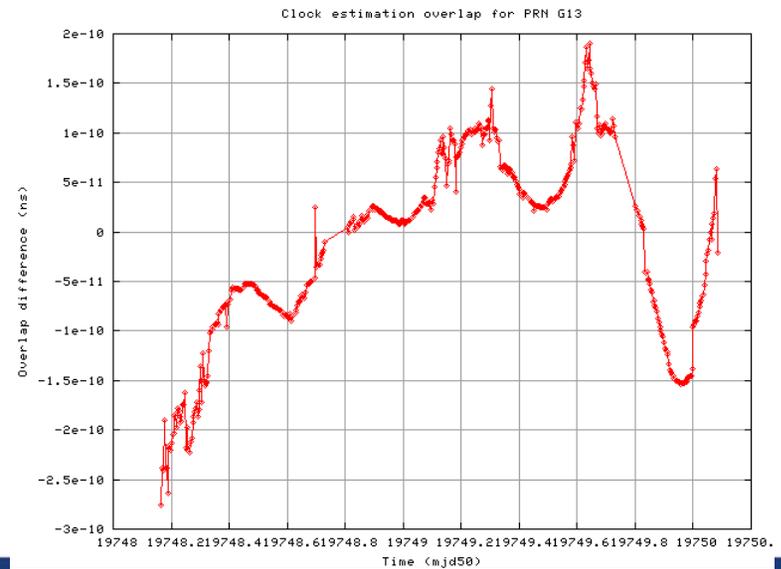
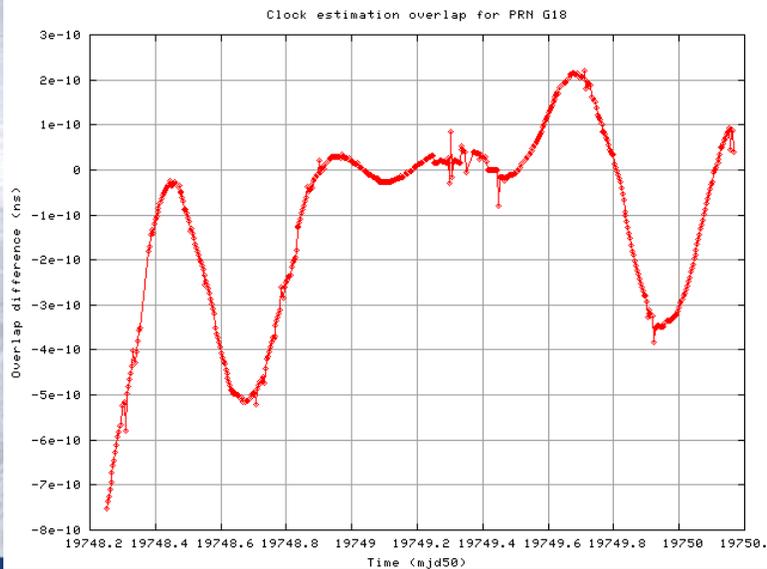
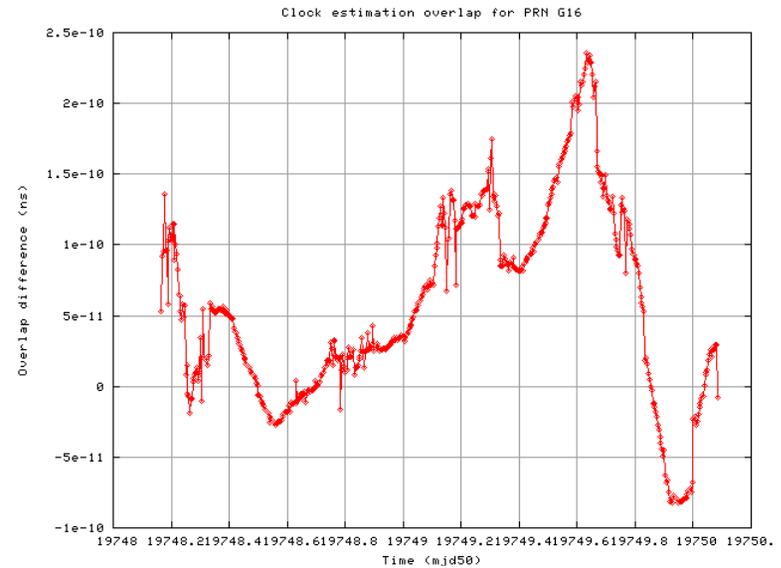
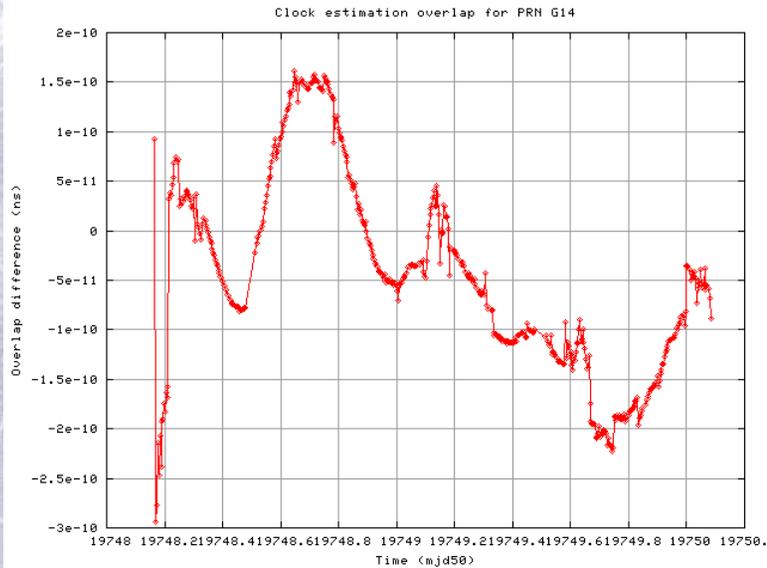
Carrier Phase measurements (1 day = 12 sessions)

Error bars show variability across sessions



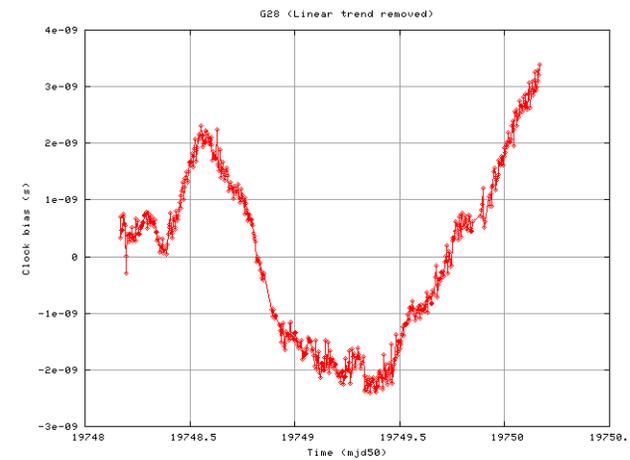
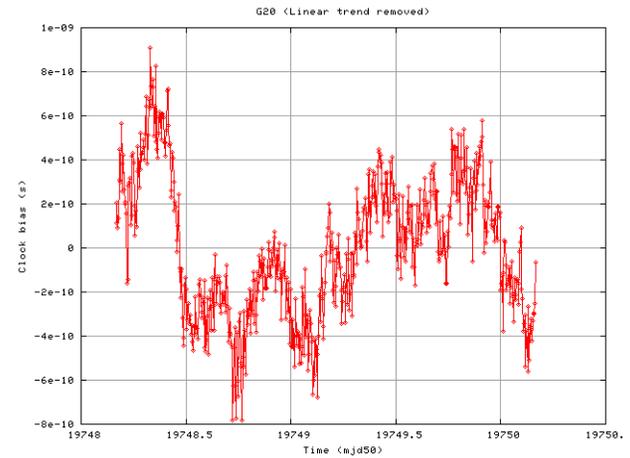
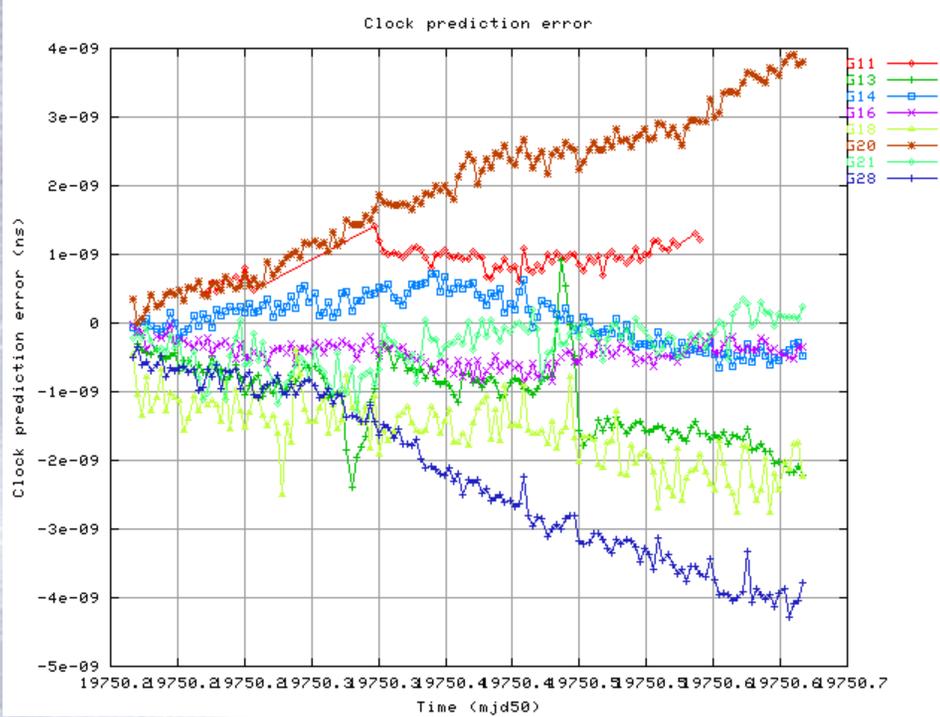


GMV Preliminary Results (3)





GMV Preliminary Results (4)





GMV SISA (1)

- SISA is a bound of the orbit and clock errors at WUL with a certain confidence level
 - SISA is a prediction
 - "Fault-free" state
- Baseline SISA algorithm is based on off-line analysis of the accuracy of past predictions
 - Bounding distribution (CDF sense)
 - Confidence interval
 - Underlying hypothesis: Gaussian behaviour
- The deterministic error of the broadcast ephemeris and clock model is computed and added



GMV SISA (2)

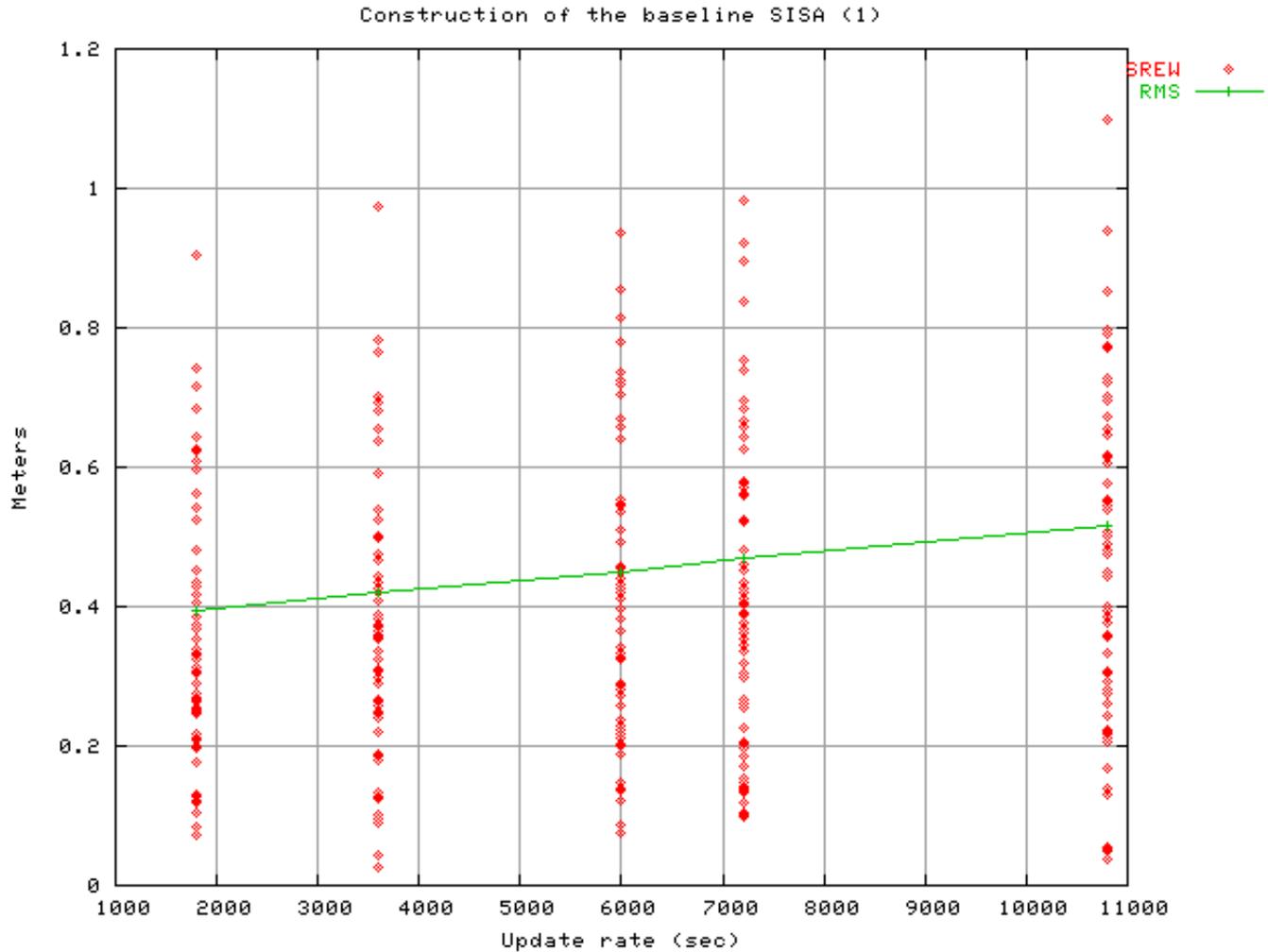
- SISA performances will be studied
 - Confidence level
 - Update rate
 - Bounding performances
- Different formats will be analysed
 - Scalar, vector, matrix
 - Constant, linear degradation with time



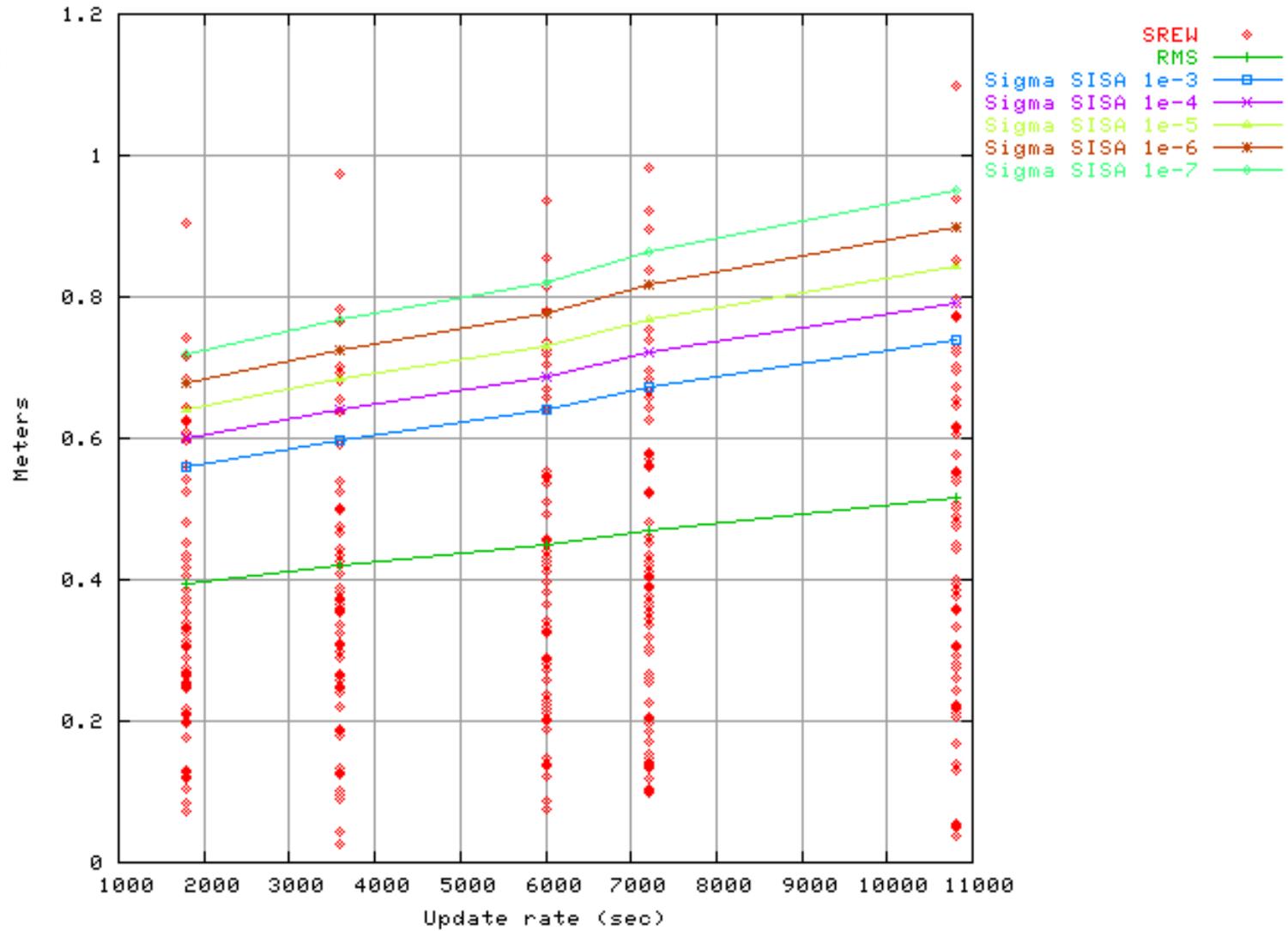
GMV SISA (3)

- Additional experimentation is planned on the “indicators” approach
 - Parameters from the OD&TS process potentially correlated with the user error
 - Residuals
 - Computed clock stability
 - They may be used to increase the SISA
 - If value exceeds a threshold
 - Through a multiplying factor
- Thorough analysis of performances may lead to the definition of additional “indicators”
 - Depth of Coverage
 - Others

- (1) PRN11, 5 days



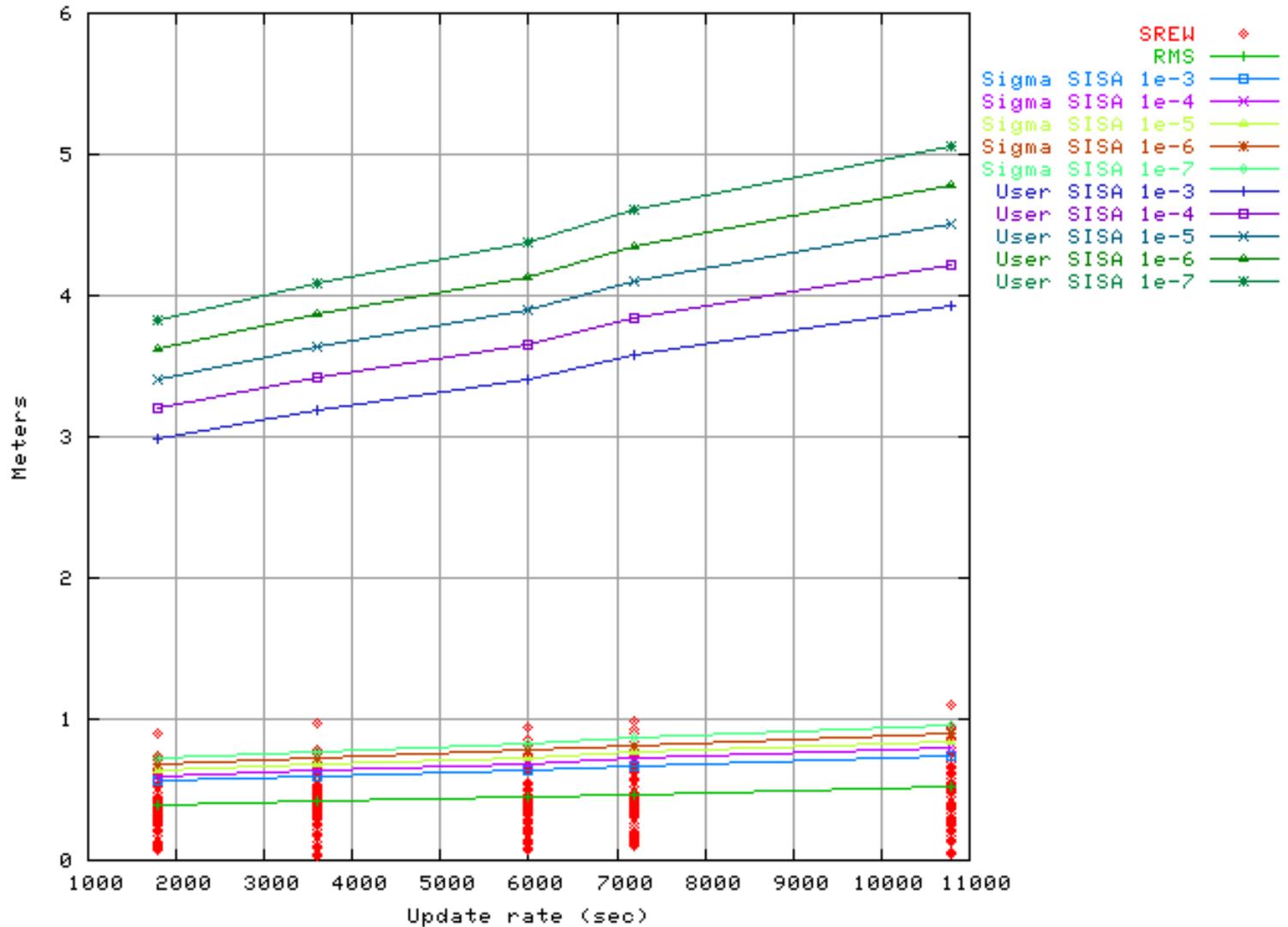
Construction of the baseline SISA (2)





EXAMPLE OF BASELINE SISA

Construction of the baseline SISA (3), User Confidence Level 1e-7





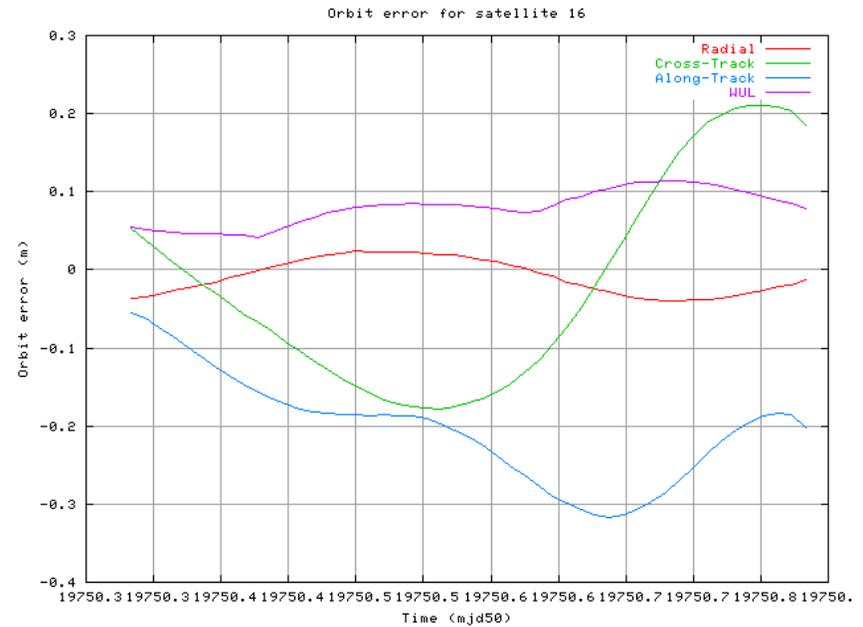
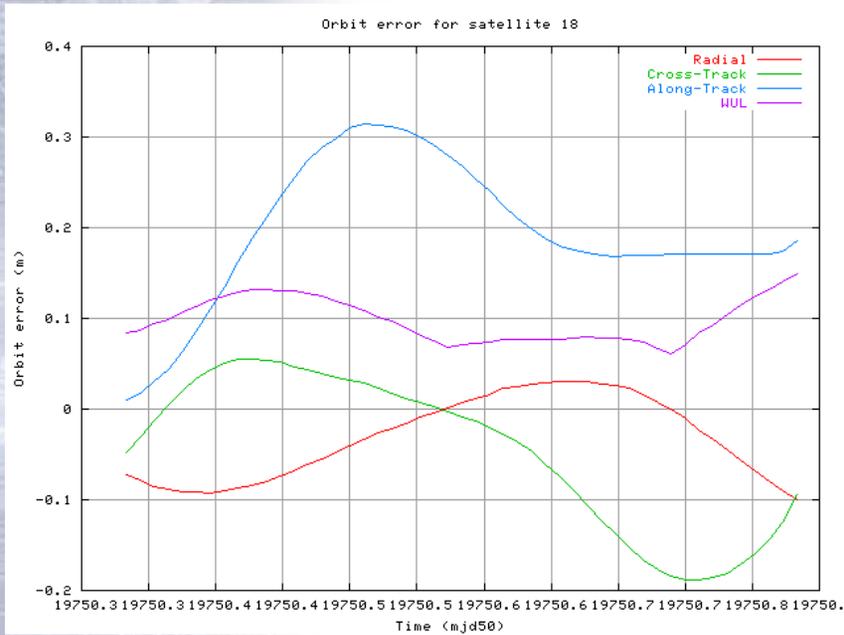
GMV Conclusions

- An experimentation environment has been setup to experiment with prototypes of Galileo algorithms
 - GPS
 - Stringent development standards
 - Use of IGS data and products
 - Routine generation of Core Products
- Baseline definition of algorithms
 - Alternatives implemented, to be tested
- OD&TS aims at reliable orbit prediction
 - SISA



GMV More Pictures

○ Example of Orbit Prediction error





GMV More Pictures

